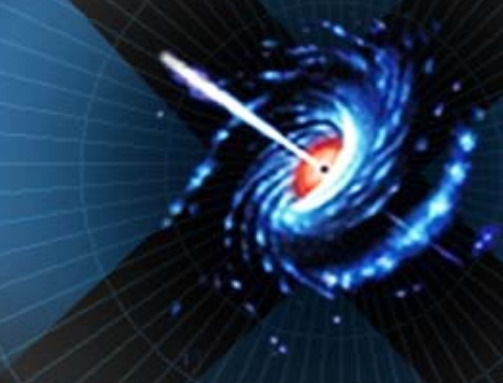
Constellation-X Facility Science Team Meeting (FST) — Oct. 14/15, 2004

Constellation X

The Constellation X-ray Mission



The SXT and New Configurations

Rob Petre

SXT Lead Scientist

Robert.petre-1@nasa.gov

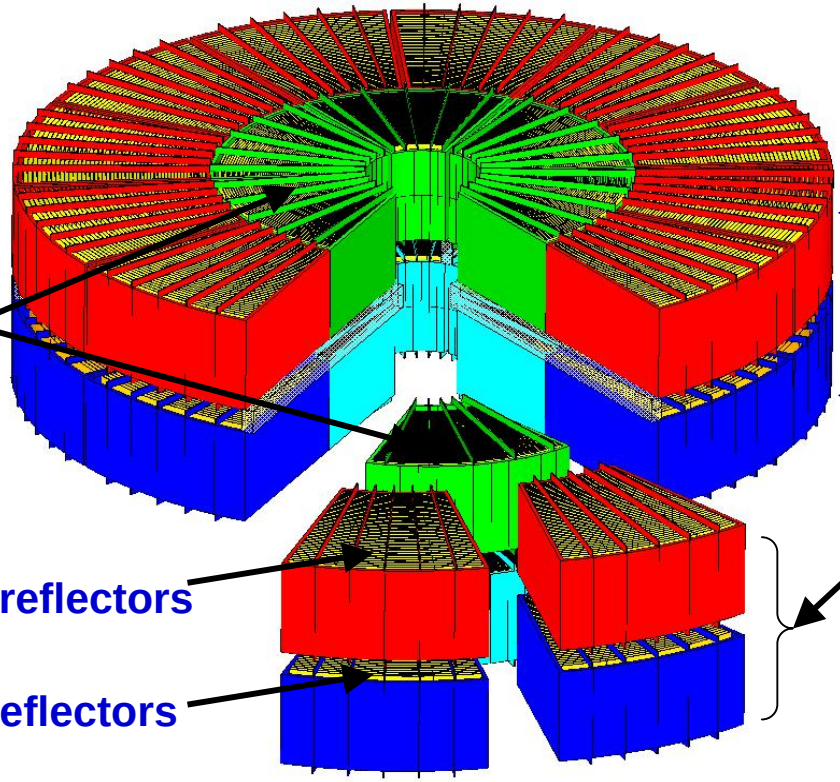
Goddard Space Flight Center

NASA

Applying current SXT approach to new Con-X configurations - 1

- For a single telescope system, given no other constraints, the most straightforward approach is make everything two times larger:
  - 20 m focal length
  - 3.2 m diameter
  - 40 cm segment length
  - 800 μm substrate
- Benefits:
  - Linear tolerances double (angular tolerances remain constant)
  - Alternatively, maintaining linear tolerances provides incremental performance improvement
- Drawbacks:
  - Mass increases by factor of >8
  - Heater power becomes >4 times larger
  - Substrates become unwieldy, if large enough pieces can be found
    - Full substrate metrology would become impossible
  - New alignment and calibration facilities would be required (existing ones are marginal for baseline)

SXT Incorporates Modular Approach and Segmented Reflectors



Inner modules (6)

Outer modules (12)

2x20 cm mirror length

Parabolic (P) reflectors

Hyperbolic (H) reflectors

1.6 m diameter at P-H intersection

Applying current SXT approach to new Con-X configurations - 2

- A more practical approach, given available substrate material:
  - Maintain current substrate thickness - reduces substrate mass by ~2
  - Maintain current substrate and module dimensions
    - More modules, more structural mass
    - Slightly larger diameter needed to compensate
    - Conserving f/number then requires slightly longer focal length
  - Overall mass is probably 5 times that of 1.6 m baseline
  - Increased heater power requirement still applies
- The simplest baseline single mirror has ~22 m focal length and ~3.5 m diameter
- Such a mirror is as buildable as the current baseline

General considerations regarding a new mirror design

- Modular design makes scaling to a larger SXT feasible with no imaging performance loss
- Single telescope diameter must be >3.2 m to meet the Constellation-X area requirement
- F/number (focal length) increases beyond ~6 provide only minor increases to collecting area
  - Increased plate scale with larger f/number leads to higher non-X-ray background
- Modular approach allows for nonstandard aperture cross sections
- Increased system size offers major assembly/alignment/calibration challenges

Prospects and challenges for improved angular resolution

- SXT system requirement is 15” HPD, goal is 5”
  - Requires ~3.5” SXT mirror
- Error budget for 5” HPD system exists - all tolerances shrink by factor of ~3
- Recent progress on reflectors brings meeting resolution goal into the realm of possibility
- Modular approach keeps problem tractable

Baseline SXT Angular Resolution Error Budget

Contributors (HPD - arcsec)	Rqmt	Margin	Allocations					Rationale
RGS Resolution	15.00	3.92	14.48					4 satellites, post-processed
• Co-add 4 satellites				1.00				Superposition of data using X-ray centroids
• On-Orbit Telescope - single satellite				14.12				RSS
• CCD pixelization error				0.41				0.5 arcsec pixels
• Grating resolution error				3.00				Estimate
XMS Resolution	15.00	4.95	14.16					4 satellites, post-processed
Co-add 4 satellites				1.00				Superposition of data using X-ray centroids
On-Orbit Telescope - single satellite				14.12				RSS
• Calorimeter pixelization error					4.08			5 arcsec pixels
• Telescope level effects					5.20			RSS
- Image reconstruction errors (over obs)						4.24		RSS
- SXT/Telescope mounting strain						2.00		Eng. estimate based on Chandra experience
- SXT/SI vibration effects						2.00		Chandra experience (jitter)
- SXT/SI misalignment (off-axis error)						1.00		Chandra experience
- SXT/SI focus error						0.20		Analysis
• SXT FMA - on-orbit performance					12.48			RSS
- SXT FMA launch shifts						2.00		Eng. est. based on Chandra
- Thermal errors						2.24		RSS
- Material stability effects						1.00		Est. based on Chandra work
- SXT FMA, as built						12.07		RSS
-- Gravity release							1.50	FEA analysis using vertical assy
-- Bonding strain							3.00	Eng. estimate, analysis in process
-- Alignment errors (using CDA)							3.38	RSS
-- Installation in housing							5.00	Est. based on OAP1 testing
-- Optical elements							9.90	Est. based on tech dev program

- ***Achievement of 15 arc second system resolution requires <12.5 arc second SXT resolution***
- ***Largest SXT error budget component is the reflector figure***

Improvements necessary for higher angular resolution - 1

- Substrates - steady progress toward improved quality and consistency
  - Substrates supporting 5” are foreseeable using current approach
- Metrology - now competes with substrates as most pressing technical challenge
  - New, state-of-the-art tools, like high speed interferometer, will improve precision and repeatability in some crucial spatial frequency domains
  - Fixturing is the most fundamental problem
- Mandrels - surface figure must be improved by a factor of ~2
  - This will require the development of new metrological approaches at Zeiss
  - A 2” HPD mandrel (50 m focal length) was made for XEUS - almost good enough
- Fixturing - modular approach keeps problem tractable
  - Housings must be considerably stiffer

Improvements necessary for higher angular resolution - 2

- **Alignment - accuracy must be improved by a factor of ~3**
  - Piezoelectic actuators have needed accuracy
  - 60 degree arcs make CDA measurements ambiguous; shorter arcs will exacerbate difficulty
  - Gravity effects become much more prominent
  - Alignment must be carried out in thermally stable environment
- **Calibration - entirely new facility must be developed, preferably vertical**
- **Thermal - CTE-matched materials are essential**
  - Elimination of epoxy is highly desirable to remove bi-layer effect
  - Allowed temperature and gradient range becomes a major engineering challenge, from assembly through flight
  - Ideally, zero-CTE materials should be used (ULE glass, CFC structure)

Summary

- **The current SXT approach is amenable to new configurations**
  - **Modular configuration allows for non-standard aperture cross sections**
  - **Caution must be exercised about increased mass**
- **The prospects for approaching 5” angular resolution are promising, but challenging**
  - **Steady progress on reflectors makes success possible**
  - **Largest challenges are alignment and thermal design**
  - **Project must recognize need for capital investments (metrology, alignment, calibration)**